GUIDE TO

THIRTY-EIGHTH ANNUAL FIELD CONFERENCE

OF THE

SECTION OF GEOLOGY

OF THE

OHIO ACADEMY OF SCIENCE

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GEOLOGY OF THE HIGHLAND-ADAMS COUNTY AREA

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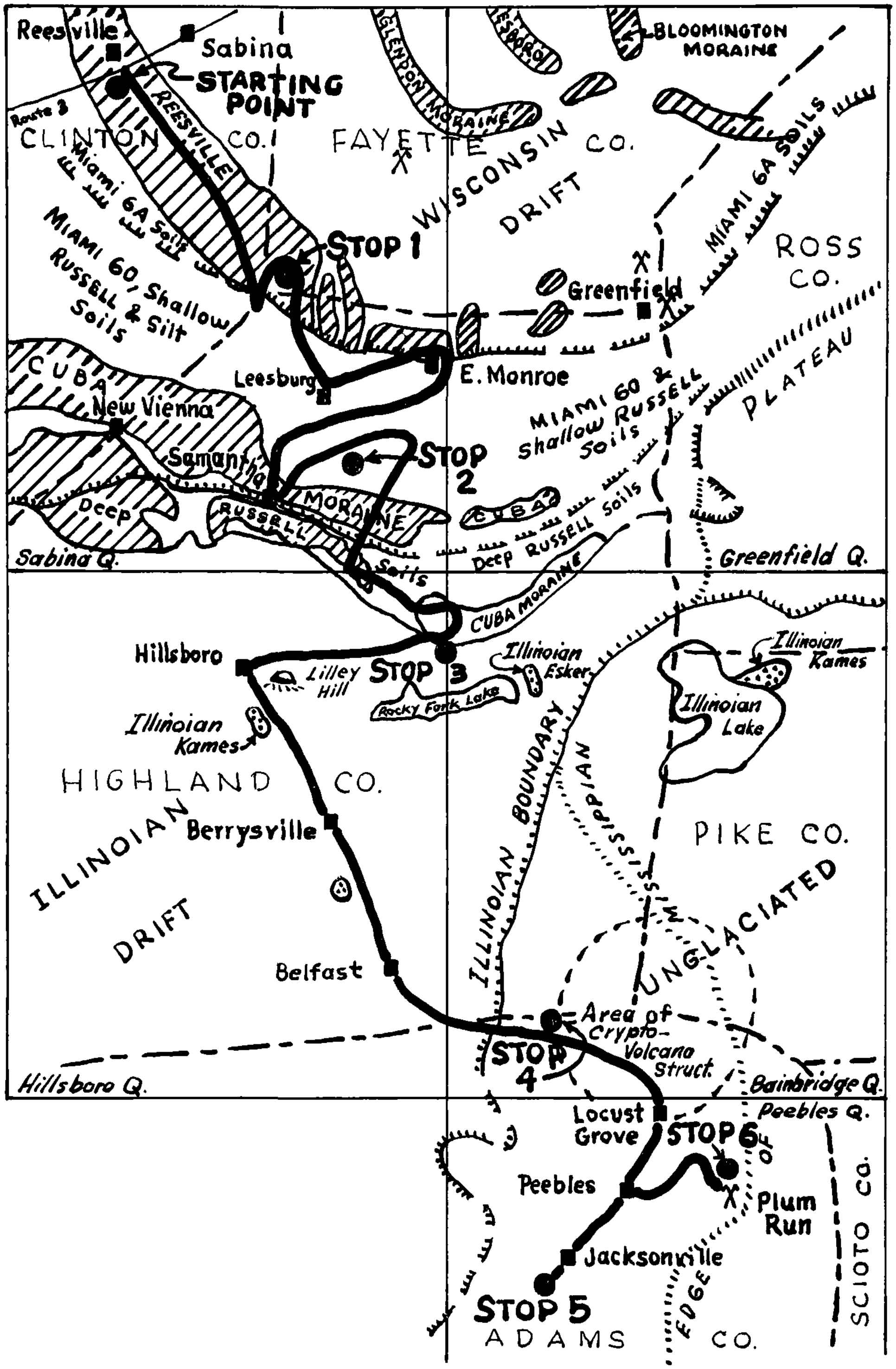

Figure 1.- Generalized Glacial Map and Route of Field Trip Through Highland and Adams Counties.

THE GEOLOGY OF THE HIGHLAND-ADAMS COUNTY AREA

Leaders: Jane L. Forsyth and Richard S. Bowman

ACKNOWLEDGEMENTS

This trip, prepared by Jane Forsyth and Dick Bowman, has drawn heavily on the already-prepared material in the 1961 G.S.A. field guide for the trips presented in conjunction with the Cincinnati meetings. Other individual bits of stratigraphic information have been gleaned from Dr. Charles Summerson regarding some aspects of the cryptovolcanic area, Dr. J.E. Carman regarding the interpretation of the Hillsboro sandstone, and Mr. Robert Alberts of American Aggregates Corp. regarding the Brassfield.

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INTRODUCTION

The general purpose of this trip is to present the bedrock and glacial geology of the Highland-Adams County area. In terms of bedrock, this means the Silurian section, which is actually far easier to observe in Adams County. Therefore, the afternoon will be spent in Adams County at two excellent exposures which, together, present the entire Silurian column from the uppermost Ordovician unit, the Elkhorn shale, up to the lowest Devonian formation, the Ohio shale.

The morning's trip will lie mainly in northern Highland County, the only place in the state where till of "early" Wisconsin age, as originally defined by Goldthwait and Forsyth, is present. By the use of three short stops and many car window views, the various "late" Wisconsin and "early" Wisconsin soils and their associated deposits will be presented. A Miami 6A soil will be observed on the Reesville moraine north of Leesburg; a Miami 60 or shallow Russell soil will be seen near the Inner Cuba moraine east of Samantha; and a deep Russell soil will be seen on the Outer Cuba moraine east of Boston.

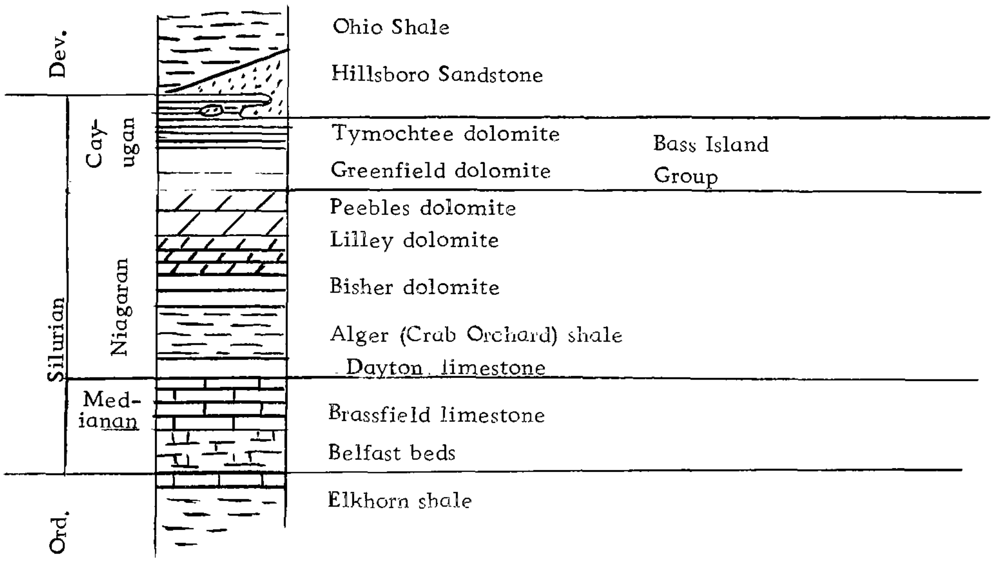


Figure 2.- Generalized Stratigraphic Section for Highland and Adams Counties.

STRATIGRAPHY

The following paragraphs are quoted from the G. S. A. Guidebook for Field Trips Cincinnati Meeting, 1961, pages 264-265.

Throughout Ohio, Silurian rocks are nowhere as accessible to examination as in Highland and Adams Counties. Here, deposits representing the Medinan, Niagaran, and Cayugan series are excellently exposed along the major drainage routes as well as in numerous artificial cuts.

The thickest and lithologically most variable part of this section occurs in the Niagaran series. For this reason, the Niagaran succession has been the target for a considerable amount of revision regarding its subdivision. Likewise, different proposed correlations of the Niagaran formations in southern Ohio with those occurring elsewhere in Ohio have been largely due to distinctly different lithologies and dissimilar faunas.

The presently accepted Silurian section in Adams and Highland Counties is as follows:

(overlain by Devonian Ohio shale and locally by Hillsboro sandstone) *

Cayugan series
- Tymochtee formation
- Greenfield formation

Bass Island Group

Niagaran series
- Peebles formation
- Lilley formation
- Bisher formation
- Alger formation
- Dayton formation

Medinan series
- Brassfield formation

(underlain by Belfast transitional beds and Ordovician Elkhorn shale) *

* Insertions are additions to G. S. A. Guidebook section.

Elkhorn shale

The Elkhorn, uppermost unit of the famous fossiliferous Richmond Series, is basically a greenish calcareous shale with reddish bands near the upper contact. Fossils are far less common in this unit than they are farther down in the Ordovician section.

Brassfield Limestone (Belfast beds at base)

Though not regarded as of formational status and not recognized elsewhere in Ohio, this locality is only 2 miles south of the type locality of the so-called Belfast beds. These strata, limier than the Elkhorn but still containing some shale zones within the section, are interpreted to represent the transition from the Ordovician shale environment to the early Silurian limestone depositional setting.

The Brassfield limestone ranges in thickness from 26 feet in northwestern Highland County to more than 55 feet in Adams County. It is a crystalline limestone that varies in color from bluish-gray to pink and locally is nearly white, with some brown layers in the upper part of the formation. The Brassfield limestone in Highland and Adam Counties is a series of limestone beds varying from 0.1 to 0.75 foot in thickness and averaging 0.4 foot, separated by shaly partings. The shaly partings are more abundant in the upper part of the Brassfield limestone and the percentage of shale increases from northwestern Highland County toward the Ohio River.

The following paragraphs are quoted from the G. S. A. Guidebook for Field Trips Cincinnati Meeting, 1961, pages 265 thru 269.

Dayton Formation

This oldest formation in the Niagaran series is represented by 2 to 7 feet of gray to greenish-gray, fine-grained limestone that is nearly always very dense and hard. Its contact with the underlying Brassfield is regarded as disconformable, a feature which is quite striking where the Dayton beds truncate cross-bedded structure in the Brassfield. At many places in southern Ohio the Dayton is apparently missing in the Niagaran section.

Alger Formation

The only noncarbonate subdivision in the Niagaran of Adams and Highland Counties is the Alger formation. This clay shale has been formerly identified as Niagara shale (Foerste, 1906), Crab Orchard clay shale (Foerste, 1917), and Ribolt shale overlying Estill clay (Foerste, 1931). The term "Alger formation" is now used as proposed by Foerste in 1923 for the stratigraphic interval between the Dayton and Bisher formations.

The Alger consists of soft bluish-green clay shale that commonly weathers to a light yellow color. In places it displays shades of red and purple resembling parts of the Elkhorn formation (uppermost Cincinnatian). The upper part of the Alger includes thin, 1- to 2-inch layers of light gray dolomite at many places. The interval between these indurated layers varies from a few inches to 15 feet within the body of shale.

The thickness of Alger clay shale varies from 160 feet at the Ohio River to approximately 36 feet in northern Highland County. Although there is some local variation in thickness this formation unquestionably thins in a north-northwestward direction.

Bisher Formation

Although several lithofacies are displayed within the Bisher formation throughout southern Ohio, its most characteristic lithologic expression is that of a silty, fine-grained, even-textured dolomite that is distinctly bedded in layers varying from a few inches to 5 feet in thickness. Another common feature of this deposit is its tendency to weather rapidly to a reddish-brown or buff color.

The conformable contact between the Bisher and the underlying Alger formation is nearly always very sharp and distinct. Conversely, the contact between the Bisher and the overlying Lilley dolomite may be transitional in places and thus often is identified with difficulty.

The thickness of Bisher strata is known to vary from 84 to 23 feet in Highland County; however, much of this thickness variation is local. Its average thickness in southern Ohio is 45 feet. Regionally the Bisher thins to the northwest and west.

At most places there occurs a 1- to 3-foot fossiliferous layer of carbonate rock near the base of the Bisher. Usually the dominant fossil occurring in this layer is the brachiopod Cryptothyrella cylindrica (Hall). Lithologically this layer is commonly more coarse grained and less silty than the adjacent strata, suggesting a temporary change in the depositional environment. The relative thinness and persistence of this deposit over two counties provides an excellent stratigraphic reference bed within this formation.

The Bisher is moderately fossiliferous, particularly in those lithofacies that are less silty or argillaceous.

The most common constituents of the Bisher fauna are brachiopods, trilobites, and gastropods. Some of the characteristic species occurring in this formation are:

Brachiopoda:

Atrypa reticularis hillsboroensis Foerste
Camarotoechia Pisa (Hall and Whitfield)
Camarotoechia roadsi Foerste
Cryptothyrella cylindrica (Hall)
Leptaena rhomboidalis (Wilckens)
Rhipidomella hybrida (Sowerby)
Schellwienella tenuis (Hall)
Stegerhynchus cf. *S. neglectum* (Hall)
Stropheodonta (Brachyprion) plana Foerste

Gastropoda:

Platyceras (Platyostoma) cornutum (Hisinger)

Arthropoda:

Dalmanites brevicaudatus Foerste
Homalonotus delphinocephalus (Green)

At present 55 species are known to occur in the Bisher formation.

Lilley Formation

The greatest lithologic variation within the Niagaran of southern Ohio occurs in the Lilley formation. This carbonate rock varies from an extremely argillaceous, blue-gray dolomite to a light gray, crystalline, pure limestone. The two most prominent lithologic types displayed by the Lilley are the crinoidal carbonate lithofacies and argillaceous carbonate lithofacies.

The crinoidal carbonate aspect is not a true crinoidal rock, but is characterized by the abundance of fossil fragments, the majority of which indicate crinoidal origin. This rock is commonly light gray, medium to coarse grained, rather porous, weakly bedded or massive, and may be either a dolomite or a limestone. In places this bioclastic phase constitutes the entire Lilley succession. Where the Lilley is vertically composed of more than one general lithology, the crinoidal carbonate lithofacies always occur in the lower part immediately above the Bisher. In general, this type of Lilley thickens to the north and west.

The argillaceous carbonate lithofacies appears as an impure blue-gray, fine-grained dolomite, usually unevenly bedded with or without shale ranging from partings to beds several feet thick. This rock commonly becomes reddish when weathered.

In several localities the Lilley is entirely composed of rocks belonging to the argillaceous carbonate lithofacies. This impure phase of the Lilley generally thins to the north and west, thus becoming less predominant in Highland County than in Adams County. Where several lithofacies constitute the Lilley, particularly in Highland County, the upper beds are nearly everywhere argillaceous.

The Lilley formation lies conformably between the Bisher below and the Peebles above. Both of these contacts are commonly transitional in Highland County, but become more distinct in Adams County. For example, in Highland County the upper Bisher passes laterally into the crinoidal carbonate lithofacies of the Lilley to the north and west. In Adams County, however, the Lilley-Bisher contact is recognized by a rather abrupt change in grain size and bedding characteristics.

The common transition between the Lilley formation and the Peebles formation in Highland County is more gradual where the upper Lilley displays the crinoidal carbonate lithofacies.

Southward into Adams County the Lilley and Peebles become interbedded as one passes vertically into the other. This relationship is known to exist from Peebles, Ohio, to the Ohio River. It is interesting that the contact between these "tongues" is usually very distinct.

The Lilley formation is very fossiliferous and provides better fossil collecting than is found elsewhere in the Niagaran series in southern Ohio. Corals, brachiopods, and fragmental crinoids dominate the Lilley fauna, although gastropods and trilobites are not uncommon. There is no striking restriction of any fossil type to a particular lithofacies of the Lilley. Despite the fact that many of the forms reported from a single lithofacies are rather rare, it should not be assumed that they only existed in one lithotope during Lilley time.

Characteristic species occurring in the Lilley formation are:

Anthozoa:

- Coenites cf. C. multiporus (Hall)
- Coenites ramulosus (Hall)
- Coenites seriatus (Hall)
- Cyathophyllum roadsi Foerste
- Favosites niagarensis Hall
- Halysites cf. H. nitida Lambe
- Holophragma calceoloides Lindstrom
- Zaphrentis digoniata Foerste

Brachiopoda:

- Atrypa reticularis hillsboroensis Foerste
- Camarotoechia roadsi Foerste
- Rhipidomella hybrida (Sowerby)
- Stegerhynchus cf. S. neglectum (Hall)

Gastropoda:

- Poleumita paveyi Foerste

At present 68 species are known to occur in the Lilley formation.

Peebles Formation

The Peebles formation represents the youngest formation of the Niagaran series in southern Ohio. It is also the purest dolomite occurring in Adams and Highland Counties.

The Peebles is a light gray to bluish-gray, fine- to medium-grained dolomite displaying numerous vugs and small cavities and occurring as a massive deposit. Although this rock is extremely fossiliferous, the state of fossil preservation is very poor. Many of the characteristic cavities in the Peebles suggest the former site of fossils. These cavities commonly contain bituminous material, although this feature is local.

Because the Peebles lies unconformably beneath either the Greenfield or Ohio shale formations its original thickness is unknown. The present maximum thickness of this dolomite is known to exceed 100 feet in Highland County. Elsewhere the Peebles formation is usually 50 or 60 feet thick.

Where the Peebles underlies the Greenfield dolomite there usually occurs a clayey deposit in the depressions of the ancient Peebles surface. Small fragments of dolomite are also present within this clayey deposit. This phenomenon is known elsewhere in Ohio at the contact between the Niagaran and Cayugan series.

At many places in Adams County the upper 20 feet of Peebles is extremely decomposed where it is unconformably overlain by the Devonian Ohio shale. This very soft, friable dolomite has been incorrectly called "marl" by local residents. Although this feature demonstrates prolonged exposure to weathering, the porous character of the Peebles undoubtedly contributed to the present degree of decomposition.

The Peebles formation in southern Ohio is regarded as Guelph equivalent. Such diagnostic Guelph fossils as Fletcheria guelphensis and Megalomus canadensis are common in this deposit.

Although 31 species are known to occur in the Peebles, this faunal record is perhaps the most incomplete within the Niagaran series of southern Ohio. Chemically and physically these rocks indicate that marine conditions for life were ideal, yet diagenetic processes have obliterated much of the fossil record. The known record, however, indicates that corals were the most numerous occupants of the Peebles Sea.

Characteristic species occurring in the Peebles formation are:

Anthozoa:
- Coenites seriata (Hall)
- Favosites niagarensis Hall
- Favosites gothlandicus forma multipora Lonsdale
- Fletcheria guelphensis (Whiteaves)
- Halysites cf. H. nitida Lambe

Pelecypoda:
- Megalomus canadensis Hall

Brachiopoda:
- Pentamerus oblongus Sowerby

Gastropoda:
- Coelocaulus macrospira (Hall)

Niagaran Correlation in Ohio

Lithologic and faunal differences in the Niagaran succession exposed in southwestern and southern Ohio have obscured logical correlation between these areas. The key to this correlation lies in Highland County, where the Bisher and Lilley formations undergo their greatest physical change.

The following correlation, proposed by Bowman in 1956, is based upon a northward projection of lithologic and faunal changes occurring in the Niagaran series in Highland County.

NIAGARAN SERIES

SOUTHERN OHIO (After Foerste, 1923)	SOUTHWESTERN OHIO (After Busch, 1939)
Peebles (Guelph)	Huntington (restricted)
Lilley	Cedarville
Bisher	Springfield Euphemia
Alger	Massie Laurel Osgood
Dayton	Dayton

Bass Island Group

Only the lower two formations of the Bass Island group are represented in Highland and Adams Counties. These are the Greenfield dolomite overlain by the Tymochtee dolomite. Actually, the occurrence of this group is restricted to local areas within these counties due to the erosional elimination of much of this deposit prior to the advancement of the Devonian Sea. Thus throughout this region Devonian rocks rest unconformably upon either the Tymochtee, Greenfield, or Peebles dolomites at different localities.

The Greenfield formation is a tan to blue-gray, fine-grained dolomite nearly always distinctly bedded but displaying some massive zones near its base at places. The texture of this rock may be granular, crystalline, or slightly oolitic, but nearly always compact. Carbonaceous laminae, color banding, ripple marks, and small-scale cross-bedding are all common features in this dolomite.

The Tymochtee formation, which conformably overlies the Greenfield, is a gray to blue-gray very fine grained dolomite displaying a rather dense texture. It is always distinctly bedded and contains argillaceous partings and carbonaceous laminae. Perhaps the most interesting feature of this rock is the presence of excellently preserved mud cracks, particularly in the upper part.

Because of the erosion of Silurian rocks prior to the deposition of the Ohio shale, the original thickness of the Bass Island rocks is unknown in southern Ohio. Actually complete sections of these rocks are quite rare in this region. At the Plum Run Stone Division quarry 3 miles east of Peebles, the combined Greenfield-Tymochtee succession has a maximum thickness of 78 feet as determined by core drilling. Although this is relatively thick as compared with other areas, it is not believed to be the greatest thickness of these rocks occurring in southern Ohio.

The Greenfield and Tymochtee formations are relatively unfossiliferous. Perhaps the most commonly observed fossil in this succession is the ostracod Leperditia. Slabs covered with this form are not uncommon at the Plum Run Stone Division quarry.

Hillsboro Sandstone

The Hillsboro sandstone is a fine-grained, well-sorted friable quartz sandstone with abundant well rounded grains. It has been shown by Carman and Schillhahn (1930) to lie above the Silurian dolomites and below the Ohio shale as the initial deposit of the transgressive Devonian sea, and to fill what were weathered (dissolved?) cavities developed in the Silurian dolomites before the Devonian transgression.

Ohio Shale

The Ohio shale, of which only the basal section will be seen, is here a brown fissile shale, which may contain carbonaceous material and some small masses of pyrite and marcasite. The lower 5-10 feet are often a blue-green clay shale.

GLACIAL GEOLOGY

Pleistocene glaciers, advancing into Ohio from the north and northwest, extended completely across the plains in the west and, in the east, pushed southward up on the Appalachian Plateau for a distance of about 70 miles (see fig. 1).

Three of the four Pleistocene glaciers are known to have invaded Ohio. Most of glaciated Ohio is covered by deposits of the last, or Wisconsin glacier. Deposits of the next preceding glacier, the Illinoian, occur at the surface south of the Wisconsin boundary across most of the state, but in the northeast these deposits are restricted to a narrow belt, and in one area are completely overlapped by the younger Wisconsin drift. Illinoian deposits are presumed to underlie most of the Wisconsin drift, but only in a very few places has a buried soil or other diagnostic feature been observed that would identify the lower material as Illinoian. Pre-Illinoian deposits are recognized only locally.

Pre-Illinoian deposits have been recognized in three areas: (1) in the Cincinnati area, where the deposit, called Kansan (?) , is generally till (R. Durrell 1961, GSA Guidebook, p. 55); (2) along the Hocking River valley in central Ohio, where Kempton has mapped pre-Illinoian terraces (Kempton and Goldthwait 1959, OJS 59, p. 135); and (3) along the valley of Little Beaver Creek in northeastern Ohio, where Lessig recognizes two pre-Illinoian terraces which he would like to call Kansan and Nebraskan (1959, OJS 59, p. 48; 1959, OJS 59, p. 332; 1961, OJS 61, p. 25). Identification of deposits as pre-Illinoian is mainly on the basis of the depth andintensity of weathering of the soil developed in the deposit. In the terrace deposits of central and northeastern Ohio this intensity is indicated by the bright color of the soil and the extreme weathered state of the individual pebbles (including granites) making up the deposit. Also, terraces called pre-Illinoian lie at higher elevations than terraces identified as Illinoian or Wisconsin. In the Cincinnati area, the soil in the pre-Illinoian till is also characterized by brighter colors and a deeper profile than that develped in the younger, Illinoian till, though both soils are so deep and so strongly weathered that distinction is difficult where the till is less than 15 feet thick over the bedrock. The pre-Illinoian till appears to be limited in occurrence to upland positions, whereas Illinoian drift is present both on the uplands and in the valleys, thus providing both another means of differentiation between the two ages of till and additional substantiation for the older deposit.

Illinoian till, wherever it lies at the surface in Ohio, is always associated with characteristic soils which are consistently deeper and more weathered than those in Wisconsin deposits, but not so strongly weathered as the soils in the pre-Illinoian materials. In most places no true morainal topography is present and the topography on the Illinoian drift is simply a somewhat smoother version of that on the underlying bedrock surface. Generally in western Ohio the areas of Illinoian till are so broad and flat, except locally where recent dissection has cut through them into the underlying bedrock, that the term "till plain" is more appropriate. The till of these plains is generally covered by several feet of loess, believed by many to be of Wisconsin age. The broad flat plains of Clermont, western Adams, and southwestern Highland Counties change eastward into hills in eastern Adams and southeastern Highland Counties, as the edge of the Appalachian Plateau is approached. Here the bedrock changes from Silurian dolomite and limestone to the west to Devonian and Mississippian shale and sandstone to the east. In most of this area, the Illinoian ice advanced just to the foot of the plateau, but in much of Adams County, it did not even reach this far. The resulting small (a little over 100 square miles) unique triangular area of unglaciated limestone and dlomite in Adams County has been of special interest to Ohio ecologists (Braun 1928, Ohio Biol. Surv. Bull. 15).

Wisconsin drift mantles most of glaciated Ohio and, because of the recency of its deposition, it still retains, almost without modification, its original topographic form. As a result, a great deal more is known about its history than is known about the history of any of the pre-Wisconsin deposits. Soils have been a particularly valuable tool in the identification and mapping of the different Wisconsin drifts of western Ohio; the amount of weathering is a measure of their age, and other differences in the soils are clues to subtle but importance differences in the nature of the parent tills.

Four different "late" Wisconsin tills are recognized, on the basis of four different soils, in western Ohio. In addition, there is an older, so-called "early" Wisconsin drift of restricted extent and controversial age (Forsyth 1961, GSA Guidebook, pp. 58-61). The four soils which define the four "late" Wisconsin tills occur in irregular east-west bands parallel to end moraines and so are considered to be significant in the interpretation of the glacial history of the state. These soils, then, are in effect age designators. These soils are distinquished from each other on the basis of (1) the presence or absence of a silt (loess) cap, (2) the depth of soil development, (3) the amount of clay in the B horizon, and (4) the amount of clay in the parent till. The characteristics of these soils, and of the "early" Wisconsin soil, are summarized in the accompanying chart (fig. 3), which also includes, for comparison, the Illinoian Clermont soil. Diagnostic characteristics for each soil are circled. In western Ohio, in the Miami lobe, the area of Miami 60 soils is generally distinct from the area of silt-capped Russell soils. Farther east, however, in the Scioto lobe, these soils tend to occur together as a complex, the soil at any individual spot being identified on the basis of the thickness of its silt cap (and its morphology). Thus, because terraces listed on the chart as being associated with these two soils are all located in the Scioto lobe, no vertical line has been drawn to separate the two columns.

The deep Russell soils are recognized only in a narrow belt across Highland and western Ross Counties in the Scioto lobe. These soils are believed to represent the occurrence, at the surface, of a drift whose age, though controversial, is believed by Ohio workers to be clearly younger than Illinoian, but significantly older than all other Wisconsin deposits in Ohio (Forsyth 1957, GSA p. 1728, abst.). Also associated with this "early" Wisconsin glaciation are terraces with elevations and an intensity and depth of weathering intermediate between those of Illinoian and "late" Wisconsin age, along the

Soil characteristics / Soil Catena	Clermont	Deep Russell (Highland County only)	Russell	Miami 60	Miami 6A	Morley
Parent material	Ill. till (generally with silt cap)	Wisc. till with silt cap	Wisc. till with silt cap	Wisc. till	Wisc. till	Wisc. till
Thickness of silt cap	1-5 ft.	18-30 in. +	18-30 in. +	0-18 in.	*Gen. absent*	*Gen. absent*
Location						
moraine to north	Hartwell	Cuba	Camden	Farmersville-Reesville	Union City-Powell	Wabash
moraine to south	Ill. boundary	Wisc. boundary	Hartwell (Wisc. bound.)-Cuba	Camden-Cuba	Farmersville-Reesville	Union City (Bloomer) Powell
Location of associated terraces	Ohio V. Mohican-Kokosing-Licking Vs. Hocking V. Scioto V.	Hocking V.	Ohio V. Mohican-Kokosing-Licking Vs. Hocking V. Scioto V.		Ohio V. Mohican-Kokosing-Licking Vs. Hocking V. Scioto V.	Scioto V.
Clay content of B horizon	33-40%	33-40%	33-40%	33-38%	40-50%	45-55%
Clay content of C horizon	15-27%	15-27%	15-27%	15-27%	15-27%	28-38%
Ratio of $\frac{\text{med. av. of clay in B}}{\text{med. av. of clay in C}}$	1.7	1.7	1.7	1.7	2.1	1.5
Depth of leaching (at well-drained site)	100-120 in.	60-84 in.	35-60 in.	27-40 in.	16-25 in.	17-32 in.
Existence as buried paleosol	x	x	--	--	--	--

Figure 3.- Chart giving characteristics and distribution of the major soils developed in till in Western Ohio. Diagnostic characteristics of each soil are circled. After Forsyth, 1961, GSA Guidebook, p. 60, including information from Schafer and Heddleson.

Hocking River valley (Kempton and Goldthwait 1959, OJS 59, p. 135), and buried soils, some in gravel, some in till, but all capped by calcareous till. Most famous of the buried soils is the one in till exposed in a railroad cut and in a stream bank two miles and four miles, respectively, south of Sidney in western Ohio. Radiocarbon datings of logs from these cuts show that the overlying till was deposited 22-23,000 years ago, while the material containing or associated with the soils is considerably older (now estimated to be about 45-60,000 years B.P.); it is called "early" Wisconsin by Ohio workers (Forsyth, Goldthwait).

The glacial geology of this trip is set up to demonstrate briefly the evidence, soils and deposits, for recognizing the famous "early" Wisconsin drift here in northern Highland County.

OHIO ACADEMY OF SCIENCE FIELD TRIP

Meet at junction of routes 3 and 72 south of Reesville, 9 miles east of Wilmington. Park on route 72 just south of intersection, heading south. Group will meet at 7:45 a.m. and field trip will begin promptly at 8:00 a.m. Mileage is from road junction, approximately 0.1 miles north of (behind) where most cars will be parked.

Mileage		
Individual	Total	Road Log
0.8	0.8	Good view ahead to right (southwest) off Reesville moraine. Soils here on moraine are Miami 6A; a depth of leaching on high point just to right of road was 17 inches. Soils off the moraine to the right are characterized by locally thick cappings of silt, much windblown (loess), some water-laid. These soils are the Russell and, locally, "T" catena (developed entirely in silt) soils. Ahead, road drops down into moderately low erosional channel through moraine. Areas of poor-grade gravel occur locally, associated with such erosional channels, thin gravel being present in the bottom of the channel and in front of the moraine, like an alluvial fan, where it is associated with water-laid sand and silt.
0.9	1.7	Another good view ahead on right (southwest) to margin of the moraine. Note change in topography from moraine ahead to flat (really depositional), downslope to the right where the silt-mantled soils occur. Route descends into major erosional "through" channel ahead.
1.9	2.7	Junction of route 72 with route 729. Continue straight ahead (south) on 72.
1.9	4.6	Memphis. Continue straight ahead (south) through "town" and across Luttrell Road.
0.5	5.1	At bend in road, route begins diagonal descent off lower slopes of Reesville moraine. At this point, moraine is still present on both sides of road, but the crest is increasingly far away on the left (east).
1.7	6.8	Route passes diagonally off lee (distal) slope of moraine. Barn ("Check-R-Mix") ahead on left lies essentially on boundary, which will be parallel to and not far from the road for the next 500 feet. Soils on the moraine here are Miami 6A and off the moraine are Miami 60 or, where the capping silt is thicker, shallow Russell soils.
0.3	7.1	Cross Clinton-Highland County line and, in about 300 feet, turn left (east) on Oak Grove Road. Route here lies on ground moraine with Miami 60 soils developed in it.
0.3	7.4	Turn left again (north and then east) on Jamison Road.
0.1	7.5	Lafayette-Highland County line. Moraine boundary, which is here oriented diagonally across road, is crossed in next few hundred feet. Low cuts along road on right opposite diagonal

Mileage Individual	Mileage Total	
		farm road entrance on left are still in older till, as evidenced by presence of Miami 60 soil (32 inches to carbonates here).
0.3	7.8	STOP 1. MIAMI 6A SOIL ON REESVILLE MORAINE In this shallow road cut exposing Miami 6A soil, note silt cap, depth of leaching (23 inches measured in past), texture of B horizon, texture of C horizon, color, and amount of weathering present for comparison with soils at next two stops, which will be developed in older tills. Continue straight ahead (east).
0.5	8.3	Stop. Turn right (south) on Morris Road which here lies on crest of Reesville moraine. A depth of leaching here was once measured at 24 inches (Miami 6A soil). Note view to right (southwest) off end moraine.
0.3	8.6	Note moderate abundance of cedars along road, which here leaves moraine and descends to ground moraine. Although no bedrock is exposed here, the cedars suggest that it is not deep, and as corroboration, bedrock exposures are abundant in the valley less than a mile away to the left (east). The outer edge of the moraine may be seen to the left (east) as it leaves the road along a diagonal orientation.
0.3	8.9	Cross Fayette-Highland County line again.
0.3	9.2	Bend left (southeast) onto Oak Grove Road. Route here lies on dissected ground moraine, but Reesville end moraine can be seen, not too clearly, back to left (north) under tree line.
1.0	10.2	Descend into valley of a Lees Creek tributary. Cut at right is entirely in till, but the presence of cedars to the left suggests that locally bedrock is not deep, a suspicion substantiated in valley to left. Strata here should be the Lilley.
0.7	10.9	Route bends right onto old US 62. View to left shows Lees Creek valley, which has bedrock (Lilley) exposed in it upstream (to left of new US 62 highway), and, on the top of the upland beyond, the Reesville moraine, here cut through by many cross channels. From here east, the moraine appears to become progressively thinner as the underlying bedrock rises higher and higher, so that the extent of the moraine decreases. The moraine also shows more dissection because of the bedrock escarpment created by the Rocky Fork drainage, just south of the moraine.
0.1	11.0	Turn left (east) and stop at Junction with new US 62. Turn right (south) on US 62 and then immediately turn left (east), descending into valley of South Fork of Lees Creek. Note bedrock (Lilley) on far side of stream on left.
0.4	11.4	Cross bridge over South Fork of Lees Creek and enter Leesburg on old US 62 highway.
0.1	11.5	Stop. Turn left (northeast) onto Ohio route 28 which is Main Street here.
0.8	12.3	Pass roadside park on left and cross bridge over Lees Creek.
0.5	12.8	Rise to upland level; edge of Reesville moraine may be seen half a mile away to the north. Soil along the road here is Miami 60, once measured as 26 inches to carbonates. Road is

Mileage Individual	Mileage Total	
		crossing dissected ground moraine; on each subsequent rise, as we continue ahead (east), edge of moraine will be closer until finally road rises up onto the outermost edge of it, close to East Monroe.
0.8	13.6	At top of rise, moraine may be seen about 0.2 of a mile away to the left (north).
0.1	13.7	Edge of moraine is only 1-200 feet to left of road and approaches it ahead.
0.4	14.1	In climbing rise, outer edge of Reesville moraine is also ascended. Younger drift was once exposed in railroad cuts to right (south).
0.5	14.6	In town of East Monroe, turn right (south) off Ohio route 28 onto hard-surfaced, but unnamed road and continue south across outer margin of moraine and across railroad tracks.
		In valley of Rattlesnake Creek, which flows south through eastern East Monroe, a section with a buried soil was discovered last year. The cut lies on the east side of the creek, about 0.8-0.9 miles north of Ohio route 28. The stream has cut deeply through the Reesville moraine and its surface drift (associated with Miami 6A soils) and into underlying Pleistocene. It is my belief that the buried soil observed in this cut represents the buried equivalent of the deep Russell soil and the underlying till represents the "early" Wisconsin till. No stop is being made at this exposure because to reach it would demand a good half mile's walk cross country each way.
0.3	14.9	At slight bend in road, route passes off outer edge of Reesville moraine.
0.3	15.2	Descend valley of Lees Creek. Deep till cut at right must be in till associated with Miami 60 soils.
0.3	15.5	Cross bridge over Lees Creek. There appear to be old gravel pits (in terrace ?) ahead on left. On the slopes above note the presence of the cedars - exposures of Lilley occur here and farther upstream to the right (west). Some of the rock can be seen on the left where the road swings up and turns right on the hillslope.
0.3	15.8	Crossroads. Turn right (west).
0.6	16.4	Last view of Reesville moraine, back on hilltops to right (north), across Lees Creek valley.
0.8	17.2	At road "Y", keep ahead left (southwest) on Lover's Lane! Hill ahead is bedrock; small, long-abandoned quarry near top and to right of our road is in Greenfield dolomite.
0.6	17.8	Stop. Turn left (south) across minor road entering right onto US 62. BE CAREFUL - this is a dangerous entrance, with no good view to north and poor view to south on busy U.S. 62.
0.1	17.9	Keep right (southwest) on U.S. 62 where Ohio route 771 goes straight ahead in Y intersection.
0.3	18.2	Turn right (west) at foot of hill onto unnamed hard-surfaced road off US 62. Bedrock hill is now visible back to right (northeast). Hills ahead are also basically held up by bedrock. Land to right and left of road is ground moraine. Where the surface silt (loess) cap is less than 18 inches thick, Miami 60 soils are mapped; where the silt cap is thicker, shallow Russell soils are mapped here.

Mileage Individual	Mileage Total	
1.0	19.2	Hill ahead to right (northwest) under farm is held up by bedrock, as is ridge extended left (south) under the road from the hill. Hills far ahead to left (southwest) are also held up by bedrock, but the next end moraine, the Cuba, is also present in the far distance (really out of sight from here) on top of those bedrock hills. The topographic difference between hills of bedrock and of moraine is very subtle and never conclusive, but after working for some time in an area like Highland County, it is often possible to develop an ability to distinguish between these two kinds of hills, on the basis of minor topographic variations.
0.9	20.1	Cross minor road from right (north), stop, and then turn left (south) onto Ohio route 72. The hills ahead to the southwest are bedrock, but on top, in the far distance, is also part of the Cuba moraine.
0.9	21.0	Bedrock is 35 feet deep in well at house on left (east) side of road on rise ahead. Bedrock is not deep on the opposite, right (west) side of the road, but about half a mile away the surface is less smooth and there are minor lumps and bumps, suggesting the presence there of end moraine (the Cuba).
0.6	21.6	A good view may be had from here of the edge of the Cuba moraine, which lies only about 0.2 miles to the right (west). One to two miles west of here, the moraine is as much as 100 feet thick. Where we cross it ahead, twice, near Samantha, the crest is very low and the moraine is probably not more than 50 feet thick.
0.3	21.9	As route rises up here, it rises onto the edge of the Cuba moraine. This is the proximal side of the moraine, which is the less distinctive side, and it is held up by the bedrock hills, so the recognition of the boundary is not always easy. Note, however, the contrast between the rather smooth surface on the bedrock hills back to the northeast and the surface characterized by low, insignificant hummocks and swells here on the margin of the moraine. This is where the moraine gets thinner and smaller, so the crest is not far ahead.
0.5	22.4	Stop. Continue straight ahead (south) on US 62 for a third of a mile into Samantha. This junction lies on the low inconspicuous crest of the Inner Cuba moraine, the part of the Cuba moraine associated with Miami 60 - shallow Russell soils in Highland County. South of a line passing through Samantha is the rest of the Cuba moraine, the so-called Outer Cuba moraine, associated with the deep Russell soils and "early" Wisconsin story in Highland County. The line of demarcation, which passes through Samantha from west-northwest to east-southeast, is actually defined by the differences in the soils. The high hill to the right (southwest) is a bedrock hill; Ohio shale is reported from its higher slopes.
0.4	22.8	Turn back sharp left (northeast) just beyond bend at edge of Samantha and school on left, by Cities Service Station, and reascend low moraine crest. Note narrowness of moraine here - less than a mile from the bedrock hill behind to the southwest to the edge of the moraine up ahead.
0.6	23.4	Keep straight ahead (left) on Shortline Road, and pass diagonally off low inner edge of Inner Cuba moraine in a few tenths of a mile.
0.4	23.8	Turn right (east) on unnamed road. According to a few well records, till under this relatively flat surface is about 40 feet thick.

Mileage Individual	Mileage Total	
0.9	24.7	Note cuts along road to right and left. Soils here are the Miami 60 (where silt cap is less than 18 inches) and shallow Russell (where silt cap is more than 18 inches).
0.1	24.8	Continue straight ahead (east) by secondary road to left (north) and then to right (south).
0.4	25.2	Good exposure of Miami 60-shallow Russell soil on right side of road.
0.2	25.4	<u>STOP 2.</u> MIAMI 60 or SHALLOW RUSSELL SOIL IN GROUND MORAINE NORTH OF THE INNER CUBA MORAINE.
		The silt cap here varies in thickness, hence the use of two soils names. This is the typical soil mapped north to the edge of the Reesville moraine and south to the "Samantha line" at the north edge of the Outer Cuba moraine. Compare this soil with the one at stop 1 (and the one at stop 3) for thickness of silt cap, depth to carbonates, texture of B horizon, texture of C horizon, and intensity of weathering present. Continue straight ahead (east), noting additional cuts in the same silt-capped till.
1.5	26.9	Descent by good till soil exposure (Miami 60) on right into valley of Hardin Creek. Bedrock is exposed along almost all the length of this valley. At foot of hill, stop and turn right (southwest), heading up-valley.
0.5	27.4	Cross bridge over Hardin Creek. Note bedrock along stream bottom.
0.8	28.2	Ascend low proximal margin of the Inner Cuba moraine. Soils here are Miami 60-shallow Russell.
0.6	28.8	Crest of Inner Cuba moraine, where the till is roughly 90 feet thick. Hills ahead (south) in far distance are part of the unglaciated Mississippian escarpment.
0.8	29.6	Intersection. Continue straight ahead (southwest) on Ohio 138 (which lies ahead and to the left) down into the valley of Fall Creek. The line between the "late" Wisconsin till (Miami 60 - shallow Russell soils) and the "early" Wisconsin till (deep Russell soil) lies in the bottom of this valley and is arbitrarily drawn along the line of the creek.
0.9	30.5	Most of the slope up from the valley is bedrock-controlled, but at this point the route rises onto an area of slightly thicker till which is the eastern extension of the Outer Cuba ("early" Wisconsin, deep Russell soil) moraine. The west of the rise, however, is back onto bedrock hill. This is the area of change; to the west the moraines are wider and thicker, to the east the moraines are represented only by little remnants of thicker till among the bedrock hills.
0.3	30.8	SLOW, by bedrock exposure on right (west). Turn sharply back uphill to the left (east). Note cedars in valleys to right (south) and almost continuous exposures of bedrock along road to left. All this rock is Peebles. WARNING: In places ahead this road had a bad surface with lots of holes.
0.6	31.4	The low ridge at left (north) with the white house on top represents the eastern extension of the "early" Wisconsin moraine that was crossed a short ways back. But much of the elevation of the ridge is due to bedrock, not drift thickness, and the fartherest east extension of the ridge may be composed of more bedrock than moraine. Locally this route may also lie on small spots of moraine, though most of the hills around this road are bedrock - controlled.

Mileage Individual	Total	
0.8	32.2	Road turns left here and does not go into farmer's yard, as it appears. The hill to the right is basically bedrock - controlled, but small linear areas of end moraine are present around the lower slopes of the hill, at about the position of the road.
0.9	33.1	Stop. Continue straight ahead (east). Note presence of lumpy, hummocky land at level of road indicating local areas of end moraine laid up against the bedrock hills.
0.3	33.4	Cut in till on left shows "early" Wisconsin deep Russell profile. Because of the surface slope, there is less than a foot of surface silt and the depth of leaching is only 50 inches, but the nature of the weathering profile is that of the deep Russell soil. The topographic undulations here indicate this is one of the local areas of "early" Wisconsin end moraine - the Outer Cuba moraine in this county (Outer Cuba moraine in Clinton County is of "late" Wisconsin age.)
0.4	33.8	Road intersection. Turn left (east).
0.5	34.3	This rise is probably a bedrock - controlled hill. Well records indicate a drift thickness of 27 feet at next farm ahead and 13 feet in small valley ahead to right, 3/4 mile ahead. But beyond valley just ahead, hummocky topography suggests a patch of end moraine again. In the far distance ahead to the right (southeast), the unglaciated Mississippian escarpment may be seen.
0.7	35.0	Route drops into valley and then rises up onto more "early" Wisconsin moraine; as road rises higher, it again leaves moraine and climbs onto a bedrock-controlled hill.
0.5	35.5	Route rises up onto crest of bedrock hill. Turn right (south) just over brow of hill. An even better view of the unglaciated Mississippian escarpment may be seen from here.
0.7	36.2	Stringtown at the intersection. Continue straight ahead (south).
0.3	36.5	Ridge ahead (south) is the main crest of the relatively continuous part of the "early" Wisconsin Outer Cuba moraine, whose north-, proximal boundary lies along the stream valley ahead.
0.4	36.9	Cross morainal boundary and note striking contrast in topography - broad smooth slopes on bedrock back to the north and a lumpy, bumpy topography here, characteristic of end moraine.
0.6	37.5	Park on right just before arriving at US 50 junction. Do not block driveway. Walk across busy US 50 to road cut directly opposite parked cars.

STOP 3. DEEP RUSSELL SOIL ON "EARLY" WISCONSIN OUTER CUBA MORAINE.

Exposed in this cut is a typical deep Russell soil developed in silt-capped till. Observe carefully the differences in this soil as compared with the Miami 6A and Miami 60-shallow Russell soils seen earlier at Stops 1 and 2 noting, (1) depth of silt cap, (2) depth to carbonates, (3) texture of B horizon, (4) texture of C horizon, (5) color of soil, and (6) amount of weathering, indicated by the general nature of the broken soil surface, and by the nature of the feldspars and ferromagnesium minerals present.

Is this truly a significantly older soil, and thus an older till? If weathering had stopped in this till about 23-22,000 years ago, would it look like the buried soils at Sidney or southeast of Columbus? This is one of our main bases for proposing an "early" Wisconsin glaciation in Ohio; are we right? Could you argue affirmatively without concern with an out-of-state disbeliever?

Mileage Individual	Mileage Total	
		Crest of moraine lies just south of stop; a step in that direction will show the moraine and beyond, where the road ascends a slight rise, the Illinoian ground moraine. We will cross the end moraine crest to the west as we drive towards Hillsboro.
		Walk back to cars, turn right (west) on US 50, heading towards Hillsboro.
0.2	37.7	Crest of "early" Wisconsin Outer Cuba end moraine.
0.3	38.0	Route passes off the "early" Wisconsin Outer Cuba moraine onto what should be Illinoian ground moraine, but what is here mainly characterized by bedrock outcrops. Note small Peebles exposure in bottom of small run to right (north).
0.4	38.4	Probably Peebles on side and bottom of little drain on right (north).
0.2	38.6	Boston. Watch for small exposures of soil. Most soil here is bright red; it is certainly dominantly formed from bedrock, with very little glacial control. Elsewhere thick Illinoian drift is present.
0.5	39.1	Bedrock on left in road cut is probably Lilley.
1.3	40.4	Bedrock in relatively new (but grassed) road cut on left (south) must be Bisher. Note the bright red soil color associated with the Bisher dolomite.
0.2	40.6	Note low constructional Pleistocene terraces, such as that under the brick house on the right (north), which are probably Wisconsin in age.
0.7	41.3	Relatively new road cuts on west side of Clear Creek valley expose mixed masses of till and gravel and may represent late glacial fill.
1.0	42.3	From the sharpness of this view point it is clear that the road is climbing westward up the high strip of land between two major east-flowing streams, Clear Creek from the northwest and Rocky Fork from the west. The town of Hillsboro lies on this high strip of land.
0.4	42.7	High hill ahead on left (southwest) across valley is Lilley Hill. One of the finest exposures of the Hillsboro sandstone lies, easy to see, right along Ohio route 124 on the far side of that hill. No exposure of Hillsboro sandstone will be seen on this trip, so that spot is recorded for those who might wish to stop by at some other time. The Hillsboro is a fine-grained, well-sorted, friable quartz sandstone with abundant well rounded grains. Before the careful studies of Carman and Schillhahn (1930, Jour. of Geol. pp. 246-261), it had been reported stratigraphically within the Niagaran, within the Greenfield, and above the Greenfield (Tymochtee was not identified in any of their sections); as a result of their work, it was shown that the Hillsboro sandstone is the basal deposit of the overlapping Devonian sea after the Siluro-Devonian disconformity. Since it lies directly below the Ohio shale, the submergence here must not have come until late Devonian time. Indeed, the sandstone itself is missing in the Plum Run quarry (stop 6), but sure enough, the basal two inches of the Ohio shale (or the two inches just below the shale) is sandy!
		Near Columbus to the north, this basal sandstone is represented by the thin bed of sand grains and fragmented dolomite at the base of the middle Devonian Columbus limestone, the lowest Devonian formation in central Ohio; in northwestern Ohio, the basal Devonian rocks are the early Devonian Detroit River Group, which has at its base the Sylvania sandstone (see last year's OAS field trip guide). Thus, the sand of the advancing Devonian sea was deposited in

Mileage Individual	Total	
		early Devonian time in northwestern Ohio (Sylvania), in middle Devonian time in central Ohio (basal Columbus), and in late Devonian time in southern Ohio (Hillsboro). (information taken from Carman and Schillhahn paper and other information obtained in past from Dr. J. E. Carman). How long was the Devonian? How fast did the Devonian sea advance across Ohio? What lived on that sandy shore?
0.5	43.2	Pass roadside park on left (note glacial, not bedrock materials exposed behind it) and enter Hillsboro.
1.2	44.4	Main intersection in Hillsboro. Turn left (south) off US 50 and Main Street on Ohio route 73 and High Street. Route will follow Ohio 73 all the way to Serpent Mound Park (lunch) and Locust Grove - 23 miles.
0.3	44.7	Turn left (east) and then right (south) following Ohio route 73 in the edge of Hillsboro.
1.5	46.2	Bridge over Rocky Fork. Note exposure of Dayton and Brassfield limestones to left (east) across Rocky Fork and behind lumberyard.
0.4	46.6	Hills above to right (west) are Illinoian kames, which have been exploited in the past. Looking back to the other side (left-east), a high rock shoulder can be seen, representative of a high level surface on the Niagaran rocks. In many places Lilley or Peebles is found on this surface, but on a shoulder like this it is likely to be the Bisher that is exposed. The real reason for the high level surface is the presence, below the Bisher, of a thick shale, the Alger (Crab Orchard), which is easily eroded. Farther south in Highland County, two rock surfaces will be seen: the same high level one on the Niagaran dolomites (Peebles, Lilley, Bisher) as is seen here, and a lower one on the older Silurian limestones (Brassfield, Dayton) that lie below the Alger shale. Streams that cut below the level of the Brassfield (southern Adams County) again cut broadly and deeply because the rocks below the Brassfield (Ordovician Richmond) are again dominantly shale.
1.1	47.7	Cross bridge across South Fork of Rocky Fork.
0.9	48.6	Exposure of what is probably Illinoian till.
0.6	49.2	Exposure of Lilley dolomite on left (east) as road level rises to level of Niagaran surface.
0.9	50.1	Another exposure, on right (west), of what appears to be Illinoian till.
0.3	50.4	Enter Berrysville, on Niagaran surface. Lilley is exposed in this area. Near south edge of town are rises (1) to adjacent slopes showing slip scars at lower elevations, at the level of the underlying Alger shale, and (2) to the unglaciated Mississippian escarpment ahead to the left (southeast).
1.6	52.0	View down to right (west) into a low bedrock area (where Niagaran upland is gone) to Illinoian kames. On Niagaran upland ahead, note abundance of cedars on rock here to right (west).
2.5	54.5	Begin descent from Niagaran upland into Brush Creek valley. Outcrop on left at top of drop is Bisher (note characteristic bright red soil associated with the still-little-weathered white dolomite masses) over Alger (note this particularly good exposure of characteristic greenish color and easily weathered clay shale composition). Note presence of both colors in slump masses just beyond outcrop. Broad flat surface at foot of hill is on lower bedrock-controlled level, held up by the Brassfield-Dayton limestones below the thick Alger shale.

Mileage Individual	Total	
0.7	55.2	Enter Belfast, following Ohio route 73 as it turns left (east) in far end of town.
0.8	56.0	Bridge over Ohio Brush Creek. Cut on river shows base of Silurian Brassfield limestone (?) over Belfast beds (transitional) over Ordovician Elkhorn shales.
0.5	56.5	Road cut exposes Brassfield limestone over Belfast beds.
0.4	56.9	Brassfield limestone exposed in bank of road.
0.7	57.6	Note general flat terraine, clearly visible on topographic map, developed on Brassfield limestone, where the easily eroded Alger shale has been stripped off the much more resistant limestone.
0.8	58.4	Cross Highland-Adams County line. Stay on Ohio route 73.
0.8	59.2	Brassfield limestone is exposed along small stream on left (north) and then in road cut ahead on right (south), where it is underlain by the Belfast beds. Some Elkhorn shale may be present at the very base of this section.
0.5	59.7	More Brassfield in the road cuts. Ordovician Elkhorn shale has been reported from the stream bed here.
0.4	60.1	Brassfield limestone is exposed in farmyard to left (north).
0.3	60.4	Route lies on the broad flat terrace on the Brassfield-Dayton limestones here, and ahead at Louden. A similar level can be seen to the left (north) across the river. Ohio Brush Creek is cutting in Ordovician shale here. Above the Brassfield surface the steep rise to the upland is at the position of the Alger shale, and the upland is held up by the Niagaran dolomites. Looking at this higher level from here we would see where Bisher rocks might be present.
1.8	62.2	Entrance to Serpent Mound Historical Park. LUNCH. After about 45 minutes, group will collect near small mound near parking area.

STOP 4. THE SERPENT MOUND CRYPTOVOLCANIC STRUCTURE AND OHIO'S PREHISTORIC INDIANS

The following paragraphs are quoted from the GSA Guidebook for Field Trips Cincinnati Meeting, 1961, p. 288 thru 290.

Serpent Mound Structure

In 1936 Walter H. Bucher published a paper unfolding detailed evidence for the cryptovolcanic origin of a number of unusual features in the United States. Before and since that time a possible meteoritic origin has also been presented as an alternate explanation for these rather curious phenomena. In June, 1960 a paper by Dietz presented compelling evidence, through the discovery of shatter core structures, of impact origin for many of these structures. Thus the question of cryptovolcanic versus meteoritic impact was again reopened.

The appearance, in a later issue of Science, of the report of the discovery of the "First Natural Occurrence of Coesite" has drawn further interest to these unique structures with the hope that this new line of evidence may be of some use in resolving the question of origin.

Thus this field trip to visit one of the classic cryptoexplosive structures comes at a rather fortuitous time.

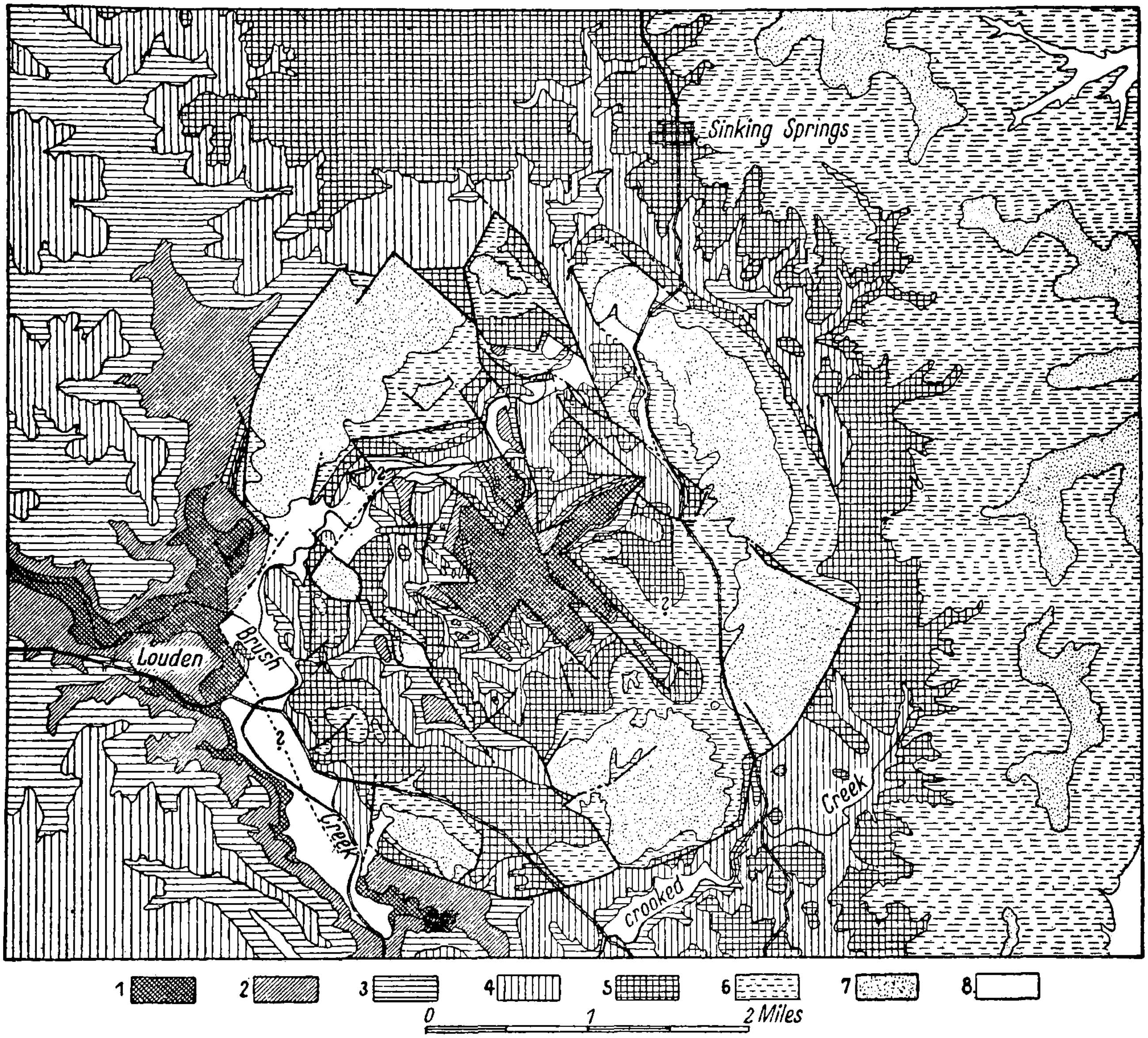
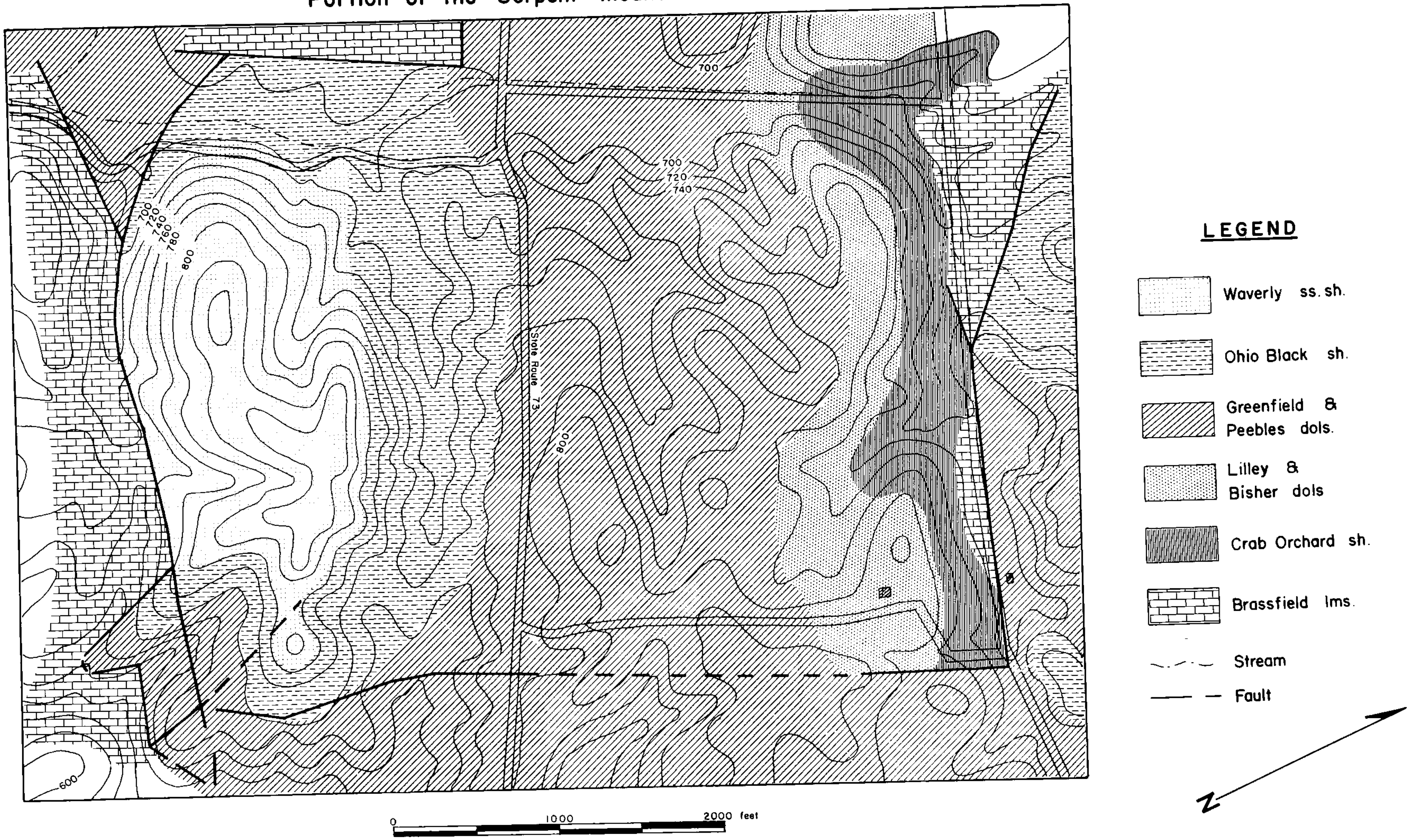


Figure 4 **- Geologic map of the Serpent Mound structure, Ohio.**

		Feet	
8.	Alluvium.		
	Cuyahoga shales and sandstones (only lower part preserved).	100±	
7.	Sunbury black shale.	10±	Lower Mississippian
	Berea sandstone.	30±	
	Bedford shale, with sandstone layers.	100±	
6.	Ohio black shale, more or less fissile.	260±	
	Hillsboro sandstone.	0-20	Devonian
5.	Greenfield dolomite.	0-40	Upper Silurian
	Peebles dolomite.	40±	
4.	Lilley dolomite.	35	Middle Silurian
	Bisher dolomite.	45	
3.	Crab Orchard clay shale.	120±	
	Dayton limestone.	0-5	
2.	Brassfield limestone.	40±	Lower Silurian
	Centerville limestone.	25±	
1.	Richmond, Maysville, Eden — Shale and limestone alternating in thin layers, total thickness about 800 feet. Only about the upper 100 feet exposed in this region except as explained in text.		Upper Ordovician

Figure 5

Portion of the Serpent Mound Structure



Dietz reported the occurrence of shatter cones at this locality, and members of the staff of the University of Cincinnati Geology Department also found specimens of this feature during a recent field trip.

The Serpent Mound structure was mapped in great detail (figure 4*) by Bucher and is believed by proponents of both theories of origin to be quite typical of the entire group of such features. It is roughly circular in outline, about 4 miles in diameter, and is characterized by severe brecciation, a stratigraphically high center (lower Eden or Cynthiana beds) and a stratigraphically depressed outer ring (Berea siltstones). Bucher calculated that the center of this structure has been raised about 350 feet in elevation and that the outer ring has been depressed more than 500 feet. It is interesting to note the following quote (Bucher, 1933, p. 1063-64):

"The outer edge of the main disturbed area is sharply defined on all sides, either by a fault or, as on the northeast side, by a sharp flexure. The chief reason for this may be that in this cryptovolcanic structure the dominant movement was downward .... over 60 percent of its surface is occupied by strata that lie more than 100 feet (30 meters) below their original altitude; less than 30 percent lie within 100 feet of their original altitude; and less than 10 percent lie more than 100 feet higher than they did originally.

"It is the more surprising, therefore, to find that here, as at Jeptha Knob, marginal anticlines lie outside the ring depression. The largest marginal anticline, that along the northeast margin, adjoins the deepest synclinal depression. The other marginal anticlines exhibit a similar tendency to lie alongside the deeper depressions. On the whole, the marginal folds are less pronounced proportionately than those in the Jeptha Knob area, probably because they lie in a relatively thick series of dolomites which tended to fracture and caused the sharply defined edges of the collapsed belt.

"The age of the structure cannot be determined definitely. It must be younger than the youngest beds involved in it, which are of lower Mississippian age, and it must be older than the middle Pleistocene, because Illinoian glacial beds lie unconformably on it. It must also have come into existence before the last period of peneplanation, for the shales and limestone of the structure have been reduced to the common erosion level of the whole region, and only the more resistant sandstones of the depressions are left as hills rising 50 to 250 feet (15 to 75 meters) above the peneplain. Unfortunately the 'age' of a peneplain is too vague a concept to be serviceable for any closer dating. In the present topography the structural ring depression appears as a circle of hills, open on the southwest side, where dolomites take the place of the sandstones that occupy most of the rest of the depression. (See U.S. Geological Survey topographic map of Bainbridge quadrangle and geologic map of Ohio (1:500,000), 1920.) Seen from a viewpoint on the edge of the escarpment which forms their inner edge, this circle of hills almost suggests a lunar crater. In it the same Mississippian sandstones that cap the erosion escarpment lie depressed below the level of the streams. The central uplift has the altitude of the general peneplain, but later erosion has deeply dissected those parts of the structure that are underlain by the dolomites and the Ohio black shale."

Ohio's Prehistoric Indians

There are eight main groups of prehistoric peoples whose artifacts have been found in Ohio. These groups are listed below in chart form. The three later groups, who represented the most people, were mound builders. Mounds here at Serpent Mound are Adena. This is learned from the remains found in the burial mounds. No remains were buried in the serpent-shaped earthwork. This feature is very unusual; the reason why the Adena mound-builders constructed it is unknown, but it was probably for some ceremonial use.

	Name	Age	Characteristics
8.	Whittlesey focus	post-Hopewell to historic	Northern Ohio - had fortified wooden stockade walls; occupied living sites a long time; used much pottery, some with handles; had flint arrowheads; used stone, bone, antler, shell for tools, weapons, decorations, dishes, musical instruments; became historic Iroquois Indians.

* Figure 21 in G. S. A. Guidebook.

	Name (con.)	Age (con.)	Characteristics (con.)
7.	Fort Ancient	post-Hopewell to historic	Southern Ohio - extended burials in cemeteries; lived in large round houses; basically an agricultural economy; had flint arrowheads (first arrows!); ornaments of many materials imported from all over U.S., but less artistic than previous peoples. (Note earthworks at Fort Ancient park are actually by Hopewell, not Fort Ancient peoples!). Became historic Shawnee Indians.
6.	Intrusive Mound	early post-Mound-builders time.	Extended and flexed burials that were "intruded" or added into already present mounds, mainly Hopewell mounds; characteristic angular bladed pentagonal flint points, plus tools of stone, bone, antler, shells, beaver teeth, slate; used tobacco, combs.
5.	Hopewell	700-2500 B.P.	Built mounds and earthworks (low ridges of dirt around margins of hilltops); elaborate extended burials or cremated burials; had excellent tools, ornaments, weapons, (had flint points, scrapers, awls, etc. but no arrow points!), musical instruments; very artistic (e.g. Fort Ancient, Fort Hill) though these earthworks were apparently not forts, but constructed for ceremonial purposes.
4.	Adena	1300-2800 B.P.	Built single conical mounds; extended burials or cremated burials; first pottery-makers in Ohio; had simple tools, ornaments, and weapons.
3.	Glacial Kame	3000-4000 B.P.	Flexed burials in glacial kames; simple stone, shell, and antler artifacts; no pottery, little known.
2.	Archaic	4000-7000 B.P.	Flexed burials; mainly a simple hunting-fishing economy; find grinding stones, shell middens.
1.	Paleo-Indian	8000-12,000 B.P.	No burials known; only characteristic fluted points (Folsom- and Yuma-type); hunters.

Glaciers left Ohio 12-14,000 years ago.

Mileage Individual	Mileage Total	
		Leave Serpent Mound Historical Park.
0.5	62.7	At junction with Ohio route 73, turn left (southeast) and enter Serpent Mound Cryptovolcanic Structure area.
0.8	63.5	Exposure of Bisher in road cut on left (north), the same rock which occurs at the level of the upland on the right (south) across the valley of Ohio Brush Creek, a good 200 feet higher! We are now well in the Serpent Mound cryptovolcanic structure, but not yet in the area of the detailed mapping of figure 5.
0.3	63.8	View back to left to abandoned quarry in Greenfield and Tymochtee dolomites. The road cut ahead, however, is in Ohio shale! We are now on the detailed map of figure 5. This map, for the next one mile only illustrates the wild geographic distribution of the geologic units resulting from the cryptovolcanic structure.
0.7	64.5	Exposure of Greenfield dolomite to left (north) here by secondary road going north and a short distance ahead to right (south) by secondary road going south.
0.4	64.9	Peebles dolomite exposed in hill on right (south).

Mileage Individual	Total	
0.1	65.00	Shattered Greenfield on left (north).
0.3	65.3	Bisher exposed in two cuts on the right (south).
0.3	65.8	Big cut on right (south) and farther ahead on left (north) is Bisher.
0.8	66.6	Several exposures here on left (north) and ahead all the way to the intersection are Lilley.
0.4	67.0	Stop. Turn right (south) from Ohio state route 73 to Ohio state route 41 and enter Locust Grove. We stay with this route most of the rest of the trip.
0.8	67.8	Bedrock on left (east) in farmyard is probably Greenfield or Tymochtee.
0.3	68.1	Route lies on flat upland here that is partly flat due to the underlying resistant dolomite (Peebles or Greenfield-Tymochtee) and partly due to fill. Here we are in a fascinating and almost entirely unstudied drainage change area. To the east of Locust Grove, Scioto Brush Creek comes southwest out of the Mississippian escarpment and, a mile and a half east of Ohio route 41, turns abruptly away from the broad western flats and plunges back into the Mississippian uplands again. Cedar Fork, which heads in the Mississippian escarpment east of Peebles (and south of Plum Run quarry), flows north toward the broad open flats and then also bends eastward to join Scioto Brush Creek. The town of Peebles itself, on the broad flat, is actually on a divide between a deeply dissecting short tributary of Ohio Brush Creek to the west, Shimer Run, and Plum Run, which flows north near town and abruptly turns east to join the Scioto Brush Creek drainage. The glacial boundary (Illinoian here) is known to lie along a generally north-south line just west of Peebles and close to the line of Ohio Brush Creek. This line was identified by Mike Stout, for many years the Soil Conservation Service soils mapper here. But locally, south of Peebles, his line has been contested by Dr. E. Lucy Braun, famous plant ecologist (and geologist) from Cincinnati who is actively studying the ecology of Adams County while she prepares valuable books like her recently published (and Academy-sponsored) "Woody Plants of Ohio." Dr. Braun, in at least one area, can tell where the glacier must have reached, on the basis of the plant distribution! Perhaps, as time goes on, we can learn to interpret more glacial information from this new approach. This would suggest that these various drainage changes, and the upland silts here as well, may relate to a fascinating glacial margin story of change and reversal, produced by ice lying to the west, that has never been studied and which should be a most interesting and profitable problem.
0.5	68.6	Monument on left (east) with the plow on top is the CAIRN OF PEACE, which was dedicated at the World's Conservation Exposition and 5th World Plowing Contest, held at Peebles in Sept. 19-20, 1957. (How odd that they should choose to locate in this one part of Ohio where the carbonate rocks were not covered by glacial deposits, this little unique triangle of Interior low Plateau!) Embedded in the monument are stones from each of the competing countries: USA - dark grey granite (Vermont?); Italy - green serpentine marble; New Zealand - red fossiliferous limestone; Belgium - grey limestone; Canada - red biotite granite; Northern Ireland - light grey granite; Netherland - fossiliferous fragmental limestone; France - grey "pseudo-eyed" granite; Sweden - red coarse-grained granite; Great Britian - greenstone; Norway - white granite; Denmark - black gabbro; Germany - white fossiliferous limestone; and Finland - red coarse-grained granite.

Mileage Individual	Total	
1.3	69.9	Enter town of Peebles. Continue south on Ohio route 41.
0.1	70.0	Bedrock, probably Lilley, in low area on right (west).
0.4	70.4	Good view of Mississippian escarpment and knobs away to left (southeast).
0.6	71.0	Bedrock, probably Lilley, exposed in farmyard on left (east).
0.7	71.7	Town of Jacksonville. Continue ahead (south) on Ohio route 41.
0.3	72.0	Good view south into deep valley of Ohio Brush Creek. Here we are looking down from Niagaran level all the way down below the Brassfield level to a valley cut into the Ordovician shales.
0.2	72.2	Pass excellent exposure on right of Bisher dolomite over Alger shale as route begins descent of valley. Our long caravan of cars can't stop here, but this is not far from our final stop 6 (Plum Run Quarry near Peebles) so some may wish to return here individually to observe the units more closely.
0.3	72.5	Bedrock along the road first on the left, then on the right, is Brassfield.
0.6	73.1	Bridge over Ohio Brush Creek. Continue ahead to first convenient turning place. Turn around and retrace route to cliffs along highway south of bridge.

STOP 5. ORDOVICIAN-SILURIAN BOUNDARY BY OHIO BRUSH CREEK

Stop 5 is an exposure of Elkhorn shale, Brassfield limestone, and Dayton limestone along Ohio route 41 on the south side of Ohio Brush Creek, Oliver Township, Adams County. These cliffs are steep; watch out for falling loose rock.

The following paragraphs are quoted from the GSA Guidebook for Field Trips Cincinnati Meeting, 1961, p. 281 - 283.

Several features of this exposure are of particular interest. This is the only exposure of the Elkhorn (fig. 6)* seen in Ohio which contains sand grains. The lithology of the sand grains has not been determined as yet, but they are probably limestone.

The Belfast bed seen here is typical for this area, and its equivalent is found in the entire outcrop area east of Dayton. It is regarded as a transition zone between the Elkhorn and Brassfield. In some places the change from the Ordovician Elkhorn to Silurian Brassfield is even more transitional than here.

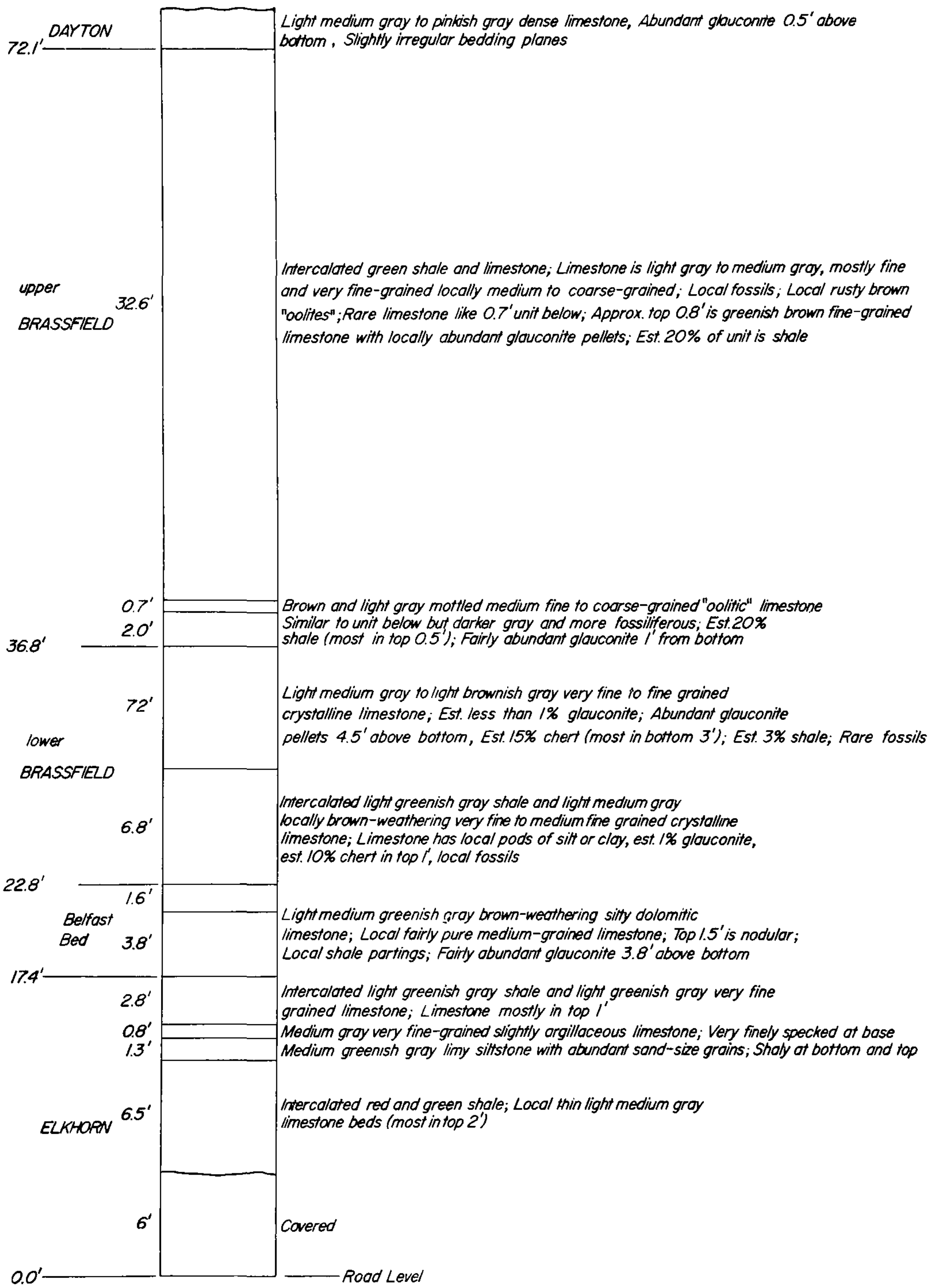
The Brassfield seen here is quite different from that north of Highland County. North of Highland County the Brassfield is divisible into two parts, an upper and a lower. The lower Brassfield in the northern outcrop area is a white or light gray, massive, medium- or coarse-grained, crystalline or sugary-textured limestone containing a high percentage of crinoid debris with little or no shale and no chert. The upper Brassfield of the northern outcrop area is essentially a light gray and pink bioclastic rock with fairly abundant green shale partings and lenses.

In contrast, here and in all the area south of Clinton County, the entire Brassfield is predominantly a light gray, fine- or medium-grained, tough, crystalline limestone--not the bioclastic type as in the northern zone. Green shale is more abundant in the southern area Brassfield than the northern Brassfield, not only in the upper part but in

* Figure 17 in G. S. A. Guidebook.

Figure 6

ELKHORN SHALE, BRASSFIELD LIMESTONE AND DAYTON LIMESTONE EXPOSURE ALONG OHIO STATE ROUTE 41 ON SOUTH SIDE OF OHIO BRUSH CREEK; ADAMS COUNTY, OLIVER TOWNSHIP



the lower part as well. Chert is also ubiquitous in the southern Brassfield in the equivalent of the lower Brassfield. Here, as in other parts of the outcrop south of Clinton County, the upper Brassfield is separated from the lower on the basis of features that are limited to the upper Brassfield north of Highland County. However, the upper and lower division here is not obvious. Two of the features found here that are almost diagnostic of the upper Brassfield are the "oolitic" limestone and brown crinoidal limestone. Throughout much of southern Ohio the "oolitic" zones of the upper Brassfield are very ferruginous and formerly were mined locally for their iron.

The Dayton limestone here has a very low dolomite content, but in most exposures in this area, as well as those in the northern outcrop area, the Dayton has a high dolomite content.

Throughout most of its outcrop the Brassfield-Dayton contact is abrupt and is considered disconformable. In most of Adams County, however, the contact varies from somewhat transitional (this exposure) to very transitional.

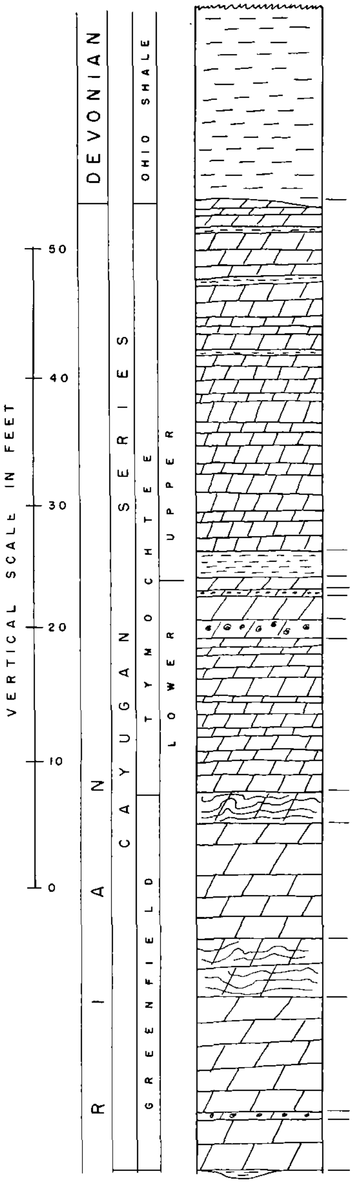
Mileage		
Individual	Total	
		The exposure of Alger shale overlain by Bisher dolomite up the hill to the north can be seen from this stop. All the covered interval represents the rest of the Alger shale interval above the Dayton limestone.
		Continue north on Ohio route 41 up hill to Jacksonville.
1.7	74.8	Jacksonville, continue straight ahead (north) on Ohio route 41.
3.7	78.5	Enter Peebles. Continue ahead (north) on Ohio route 41.
0.7	79.2	At 2nd traffic light, turn right (east) off Ohio route 41 onto Ohio route 74 between Sinclair and Pure Service Stations. Follow Ohio route 74 out of town.
0.9	80.1	Valley ahead to right (southeast) is that of Plum Run. Plum Run was one of the valleys discussed earlier (mileage 68.1) as having apparently been rerouted by what may have been the effect of the Illinoian glacier advancing eastward from the western lobe. Note how flat and broad the land is back to the west, the direction toward which the stream may have flowed at one time.
0.8	80.9	Note good view ahead (east) to the edge of the Mississippian escarpment which is held up by the Berea and Waverly sandstones and shales above the Ohio shale.
0.4	81.3	Exposures to right (southeast) along road and in yard of farm ahead are Greenfield or Tymochtee dolomite.
0.6	81.9	Turn right (south) off Ohio route 74 onto private quarry road at sign of "Plum Run Stone Division."
0.7	82.6	Cross railroad and approach plant of Plum Run Stone Division. Proceed through operation area, circling south (far) edge of pit and follow road to quarry floor.

<u>STOP 6.</u> PLUM RUN QUARRY.

The following paragraphs are quoted from the GSA Guidebook for Field Trips Cincinnati Meeting, 1961, p. 285, 287, and 288.

Introduction

For many years exposures on this quarry property have attracted geologists and students. Here, within 200



Shale ranging from black, fissile in the upper part to blue-green clay shale in lower part.

Dolomite, light gray to blue-gray, fine-grained, dense texture. Bedding distinct with some clay shale partings. Excellently preserved mud cracks along some bedding planes.

Dolomitic shale, blue-gray, weathers rapidly.

Dolomite, gray, fine-grained, hard, dense.

Dolomite, tan, very fossiliferous, porous.

Dolomite, gray to blue-gray, fine-grained, hard dense.

Dolomite, brown, fine-grained, cxl., with numerous vugs and concentric cavities. Occurs as one massive layer.

Dolomite, gray to blue-gray, fine-grained, hard, dense, distinctly bedded. This unit contains numerous carbonaceous laminae and displays some color banding.

Dolomite, tan to blue-gray, fine-grained, cxl., hard. Displays contorted primary structures.

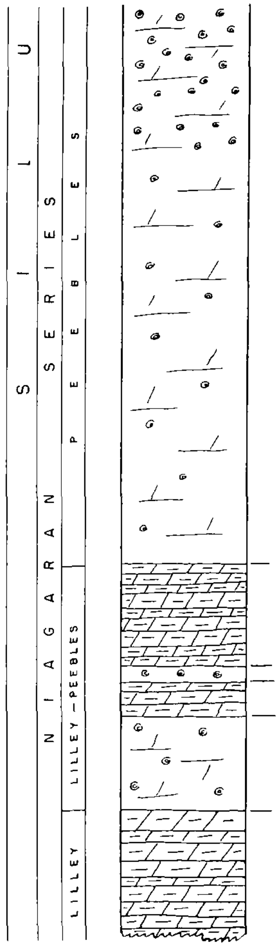
Dolomite, tan to blue-gray, fine-grained, cxl., with rather sugary texture. Distinctly bedded and containing a number of carbonaceous laminae and some color banding. Small scale cross-bedding common.

Dolomite, tan to blue-gray, fine-grained, somewhat porous, displaying some contorted primary structure.

Dolomite, tan to blue-gray, fine-grained, sugary to oölitic texture. In rather thick beds showing some carbonaceous laminae, color bands, and small scale cross-bedding.

Dolomite, blue to blue-gray, vuggy, hard.

Dolomite, light tan to gray, fine-grained, compact, sugary texture. Occurs in thick beds.



Dolomite, light gray to blue-gray, fine to medium-grained, cxl., massive but with faint bedding in lower part. Rock characterized by very porous texture with vugs particularly in upper 12 feet. Some bituminous material occurs throughout deposit. The undulating top of the Peebles has a maximum local relief of 3 feet. The depressions in this erosion surface are commonly filled with clay shale.

Dolomite, argillaceous, gray to blue-gray weathering to reddish hue. Fine to medium-grained, contains numerous fossil fragments. (Lilley interbed)

Dolomite, light gray, fine-grained, vuggy. (Peebles interbed)

Dolomite, somewhat argillaceous, gray to blue-gray, fossiliferous. (Lilley interbed)

Dolomite, light gray, fine-grained, cxl., vuggy, with some bituminous fillings. (Peebles interbed)

Dolomite, argillaceous, blue-gray weathering to reddish hue, fine-grained, irregularly bedded. Contains Coenites, Zaphrentis, Halysites and Favosites together with a considerable amount of fossil fragments. Some calcite fillings present.

Figure 7

GENERALIZED STRATIGRAPHIC SECTION OF ROCKS EXPOSED ON THE PLUM RUN STONE DIVISION PROPERTY; ADAMS COUNTY, OHIO acres, one may examine 5 geological formations ranging from Middle Silurian to Upper Devonian, 2 unconformities, and at least 15 faults. This is also the best known locality where the Peebles formation and its stratigraphic relationship with the overlying Greenfield and underlying Lilley formations may be observed.

Stratigraphy

The exposed stratigraphic section on this property consists of the Lilley, Peebles, Greenfield, Tymochtee, and Ohio shale formations.... An abandoned quarry opening on the southern part of the property best displays the Lilley, Peebles, and lower Greenfield dolomites. The floor of the active quarry adjacent to the railroad marks the top of the Peebles formation. Above this floor the entire Greenfield, Tymochtee, and the basal 15 feet of the Ohio shale may be examined.

All of the visible Lilley units on this property are part of the argillaceous carbonate lithofacies. Typically, the Lilley occurring in the abandoned quarry has become soft and somewhat reddish in color after weathering for a relatively short period of time.

Of special interest is the interbedding of the Peebles and Lilley formations at this site.... Although several of the lithologic constituents in this interbedded succession are very thin, the entire stratigraphic sequence has been identified in a core taken 5100 feet northeast of the exposure in the abandoned quarry. The contacts between "Peebles beds" and "Lilley beds" are generally very sharp, indicating a rather abrupt change in the marine environment. Chemical analyses through this interbedded part of the section also show an appreciable contrast in the percentage of Al_2O_3 and SiO_2 in the impure Lilley dolomite as opposed to the pure Peebles dolomite.

The main body of the Peebles dolomite is very massive, porous, and displays numerous vugs and cavities, particularly in the upper 12 feet. Considerable amount of bituminous material is present in this dolomite at the abandoned quarry; however, this phenomenon is not persistent throughout the entire property. Generally, the bituminous material is confined to the upper 12 feet.

The unconformable contact between the Peebles and the overlying Greenfield is quite distinctive in the abandoned quarry exposure. Several pockets of clayey material are visible in the quarry face. The presence of this argillaceous material in many depressions on the old Peebles surface has been detected throughout the property.

The average thickness of the Peebles formation above all interbedding is 45 feet. The thickness of the Lilley-Peebles interbedded succession is 20 feet.

The Greenfield formation, best exposed in the active quarry, is not readily distinguished from the overlying Tymochtee formation. In general, the Greenfield is somewhat thicker bedded and is largely tan in color as opposed to the blue-gray Tymochtee. Other distinguishing features of the Greenfield are a somewhat sugary texture and the presence of small-scale cross-bedded structures.

Approximately 4 to 5 feet above the base of the Greenfield there occurs a hard blue-gray layer that resembles the top of the Peebles. This bed varies from 4 to 10 inches in thickness and appears to be persistent throughout the property. Stylolites commonly occur in this layer as well as some sphalerite.

The Tymochtee-Greenfield contact is arbitrarily set at the top of a rather thick layer showing a considerable amount of contorted primary structure. Using this as a marker one can see that the Greenfield has a thickness variation of 22 to 30 feet in an area of 100 acres.

The Tymochtee has been divided into an upper and lower part throughout this quarry property. The line marking this division has been placed at the base of a 2-foot layer of dolomitic shale occurring 17 to 20 feet above the designated base of this formation. This bed of shale is continuous throughout the quarry property but may not continue far beyond. For this reason it is not here suggested that the Tymochtee formation be subdivided regionally.

Although the Tymochtee is relatively unfossiliferous, there exists a bed 6 to 10 inches thick below the shale unit that is quite rich in fossils. Ostracods, brachiopods, cephalopods, and pelecypods may be collected in this unit.

The unconformable contact between the Tymochtee formation and the Ohio shale is very even wherever exposed. Core drilling, however, has revealed that the local relief of this erosion surface is at least 10 feet in a horizontal distance of 445 feet.

The Ohio shale is typically a brown fissile shale containing carbonaceous material and some small masses of pyrite and marcasite. The lower 5 to 10 feet is nearly always a blue-green clay shale in which some zones of fissile shale occur. The basal 2 inches of post-Tymochtee material consists of a somewhat sandy deposit containing a considerable amount of iron sulfide mineral as well as some fossil fragments. This layer has been observed in most cores that have transected the Devonian-Silurian contact on this property.

Structure

The present active quarry is located in a northwest-southeast-trending graben . . . . Beds gently dipping one-fourth to one-half degree eastward on the northeast flank of this graben reflect the general regional dip and, therefore, were probably not affected by this local structure. Beds to the southwest of the graben, however, generally dip 2 1/2 degrees toward this structure, becoming 5 degrees in some places adjacent to the main marginal faults. Thus the principal vertical displacement along the southwest side of the graben takes place along one fault. Conversely, the main vertical displacement along the northeast side is nearly evenly distributed along two fault lines.

The lineal extent of this graben is not known. The principal fault along the southwest side, however, has been traced approximately 1 1/2 miles southeast of the active quarry, where it continues to display a vertical displacement of at least 25 feet.

A number of cross faults of small vertical displacement occur within the braben. It is interesting to note that several of these secondary faults form acute angles pointing roughly northwest. Also, several cross faults present in the northwestern part of the graben "cut off" minor faults occurring in a more southwestern part of the structure. All of this suggests that the area of greatest disturbance may lie northwest of the active quarry.

Features such as slickensides, shear zones, fault breccia, and small-scale drag folds may be observed in the active quarry.

Economic Aspect

Dolomite once taken from the abandoned quarry was used to manufacture dead burned dolomite for metallurgical use. At present, aggregate constitutes the main production of the plant. This material is selectively obtained from five ledges in the active quarry. A recent opening located in the northeast part of the property is currently being used to obtain rock from the Peebles formation.

The following chart shows the geological selectivity being followed in producing various products at Plum Run Stone Division.

Product	Formation			
	Upper Tymochtee	Lower Tymochtee	Greenfield	Peebles
Road base aggregate	X	--	--	--
Railroad ballast	--	X	--	--
Road stone	--	X	X	--
Concrete aggregate	--	X	X	--
Flux stone	--	--	--	X
Filler	X	--	--	X
Manufactured sand	--	X	X	--
Agricultural lime	--	X	X	X
Rock dust	--	X	X	X

The 1963 Ohio Academy of Science Section C field trip ends here. We hope you have enjoyed the trip and look forward to seeing you again next year.